

# HabEx 4-meter off-axis primary mirror study

Jacqueline Davis

# Habitable Exoplanet

Are we there yet??



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### telescope technology

habitable zone size = large telescope diameter

star size = high line of sight stability

high contrast = mid-to-high spatial frequency resolution  
& wavefront-error stability

diffraction limit = low/mid-spatial wavefront error

spatial resolution = line of sight stability



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### programmatic constraints

launch vehicle constraints = mass budget  
fairing size

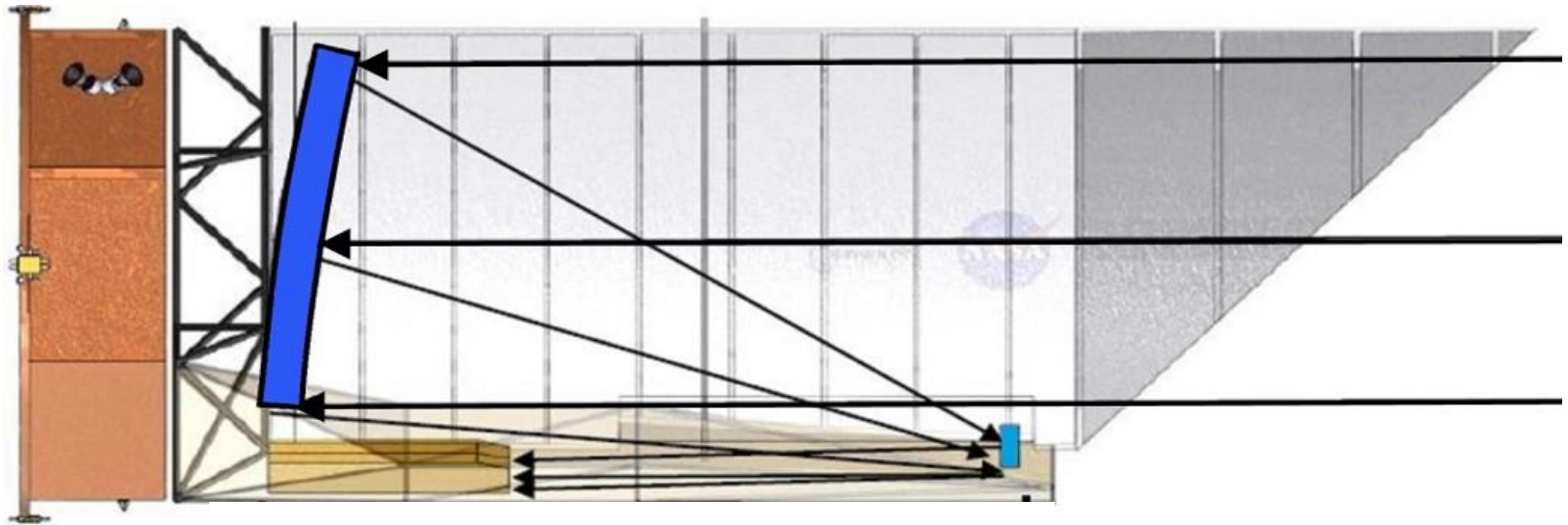
architecture telescope

budget constraints = telescope diameter



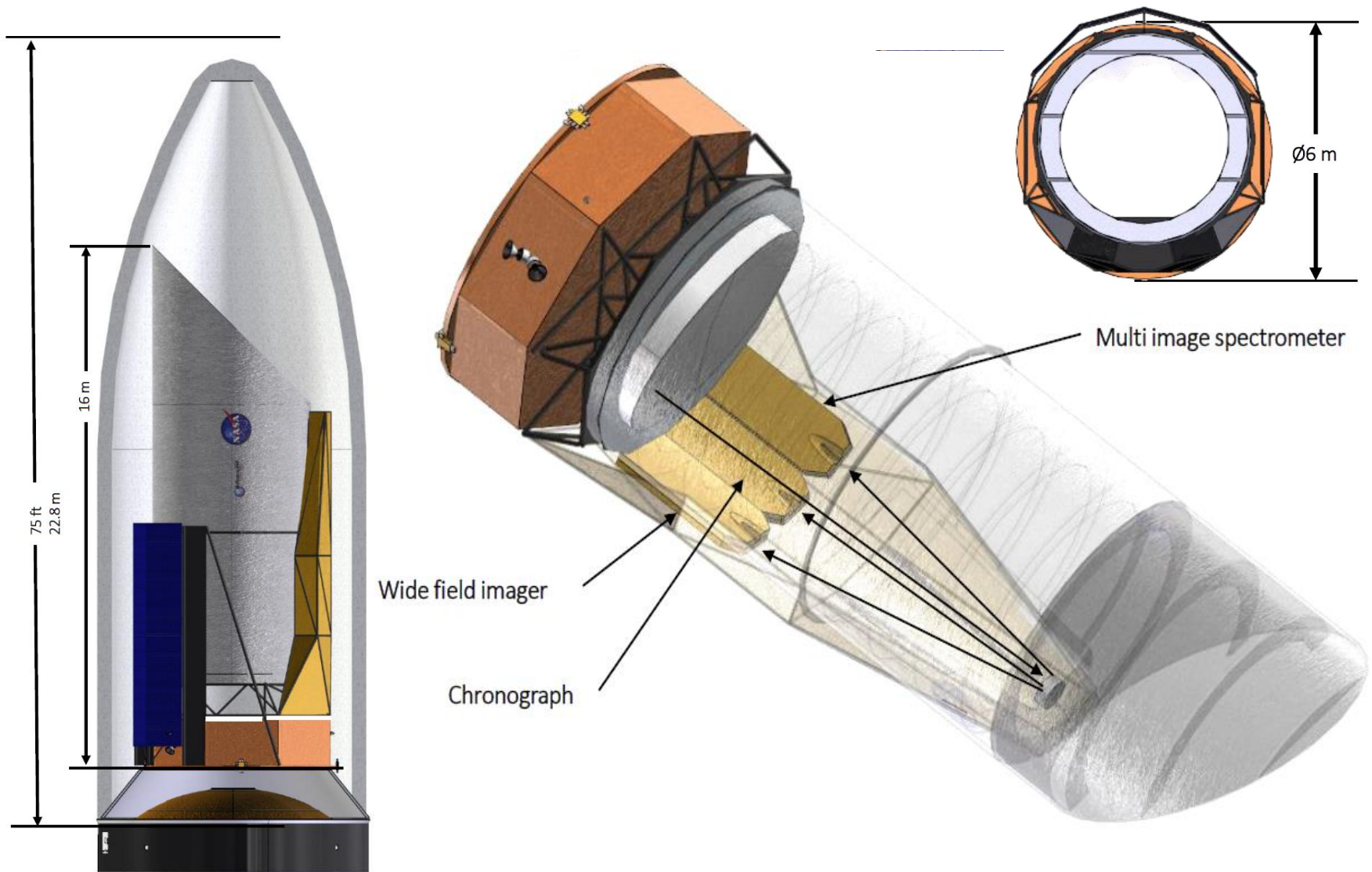
# optical telescope assembly

primary mirror assembly



secondary mirror assembly

# launch vehicle and science instruments





# Arnold Mirror Modeler

Arnold Mirror Modeler (c)2017 3.9.10.00

Num Rings: 0  
Mirror Polygon N: 1

Cell Width: 0.167  
Sgmt Dia: 4.000  
Sgmt Lip: 0.045  
Sgmt Gap: 0.1  
Sgmt Polygon N: 1

Model Statistics:  
2357 num Nodes  
7669 num Elms  
1378.45 Weight (kg)  
29.35 Area (m<sup>2</sup>)  
46.96 AD (kg/m<sup>2</sup>)  
714.44 Faces (kg)  
655.76 Core (kg)  
12.42 Edges (m)  
Milled (m<sup>3</sup>)

Archive Loaded: 3PTOUT  
Status: Finished Writing out Model  
Operation Duration: Lapsed Time: 00:00:09.655

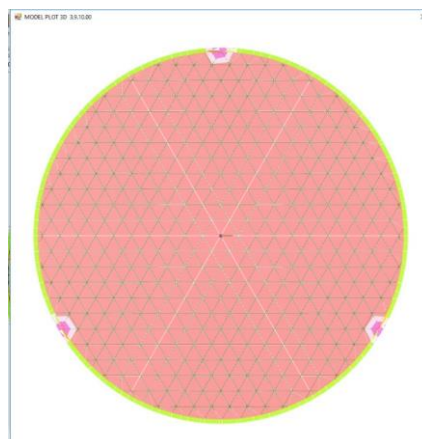
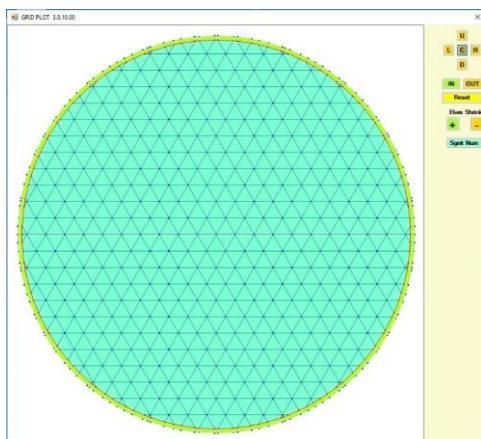
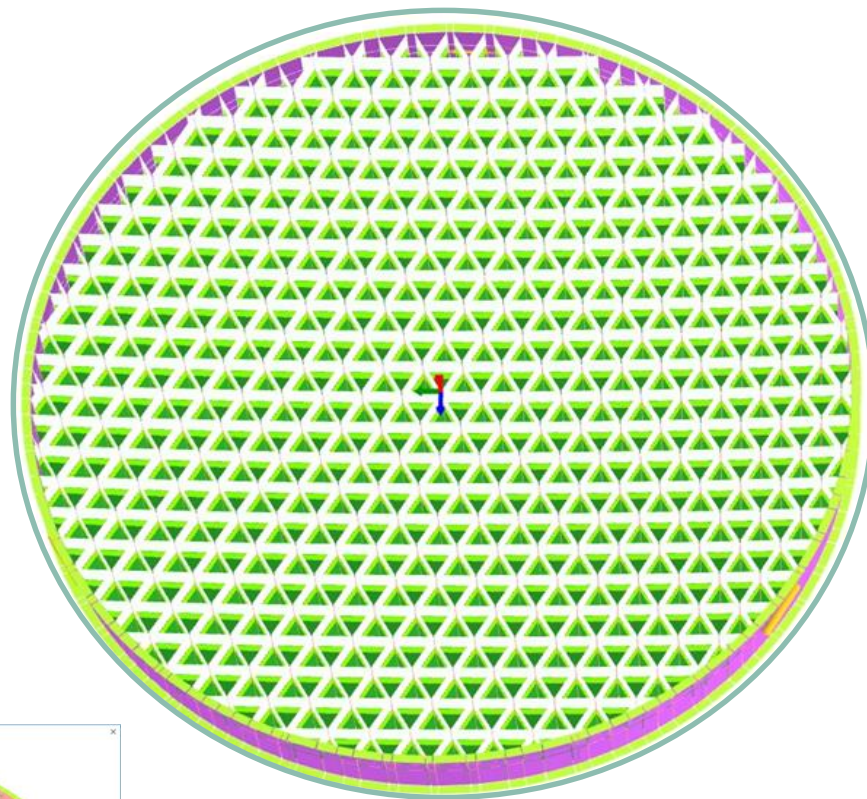
SINGLE SEGMENT  
Outer Dia A: 2  
Mirror Lip: 0.05  
Inner Dia: 0.6  
Inner Lip: 0.05

WRITE ANSYS  
WRITE ABAQUS  
WRITE NASTRAN  
DOUBLE MESH  
SAVE SETTINGS  
RESTORE ALL  
MERGE POINTS  
MERGE NODES  
TRISECT FRONT  
CREATE GRID  
MAKE SUPPORT  
CREATE MODEL  
LOCAL REFINE  
SLUMP MIRROR

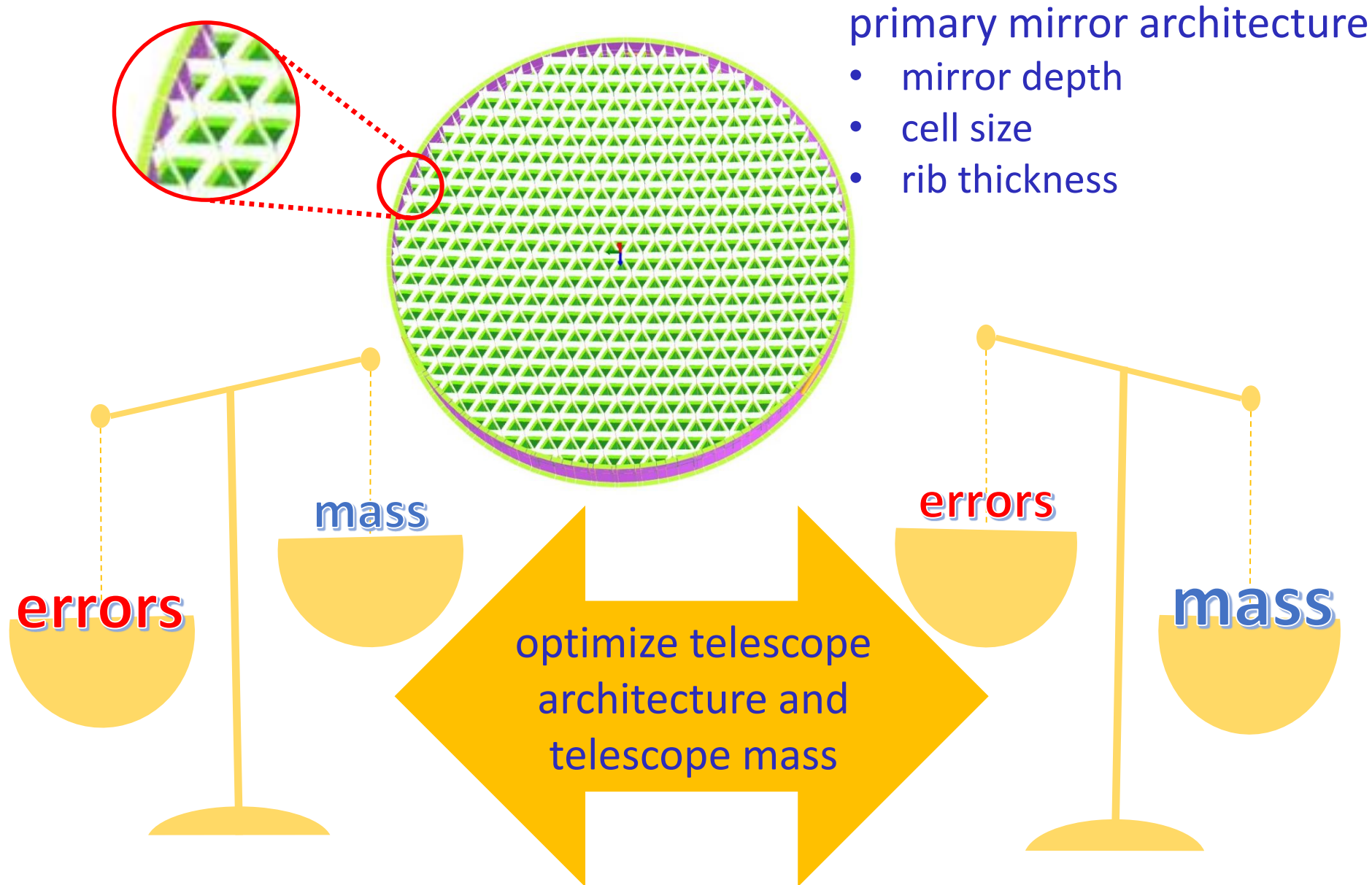
BouleMap Zernike Removal Back Profiles  
Options Grid/Model Materials Graphics Core Optical RefineMesh Wedges Sofia Edge Reals (1)  
Reals (2) Hexapod Axial Radial Tangent Bars WhiffleTree Static Random Harmonic Transient

Height (ground): 0.25 (m)  
Acceptable Near: 1E-05 (m)  
☐ Do Hexapod  
☐ Do Hexapod Pad

	Upper Dia (m)	Lower Dia (m)	Start Ang (deg)	Upper Ang (deg)	Lower Ang (deg)	Pad Dia (m)	Perim Dia (m)	Katnut xE6 (N/m)	Pad Wt (kg)	Base Wt (kg)	Three Pad
1	0.6	0.8	30	30	5	0.125	0.2	200	1	0.5	<input type="checkbox"/>
2	0.8	1	0	30	5	0.125	0.2	200	1	0.5	<input type="checkbox"/>
3	0	0	0	0	0	0	0	0	0	0	<input type="checkbox"/>
4	0	0	0	0	0	0	0	0	0	0	<input type="checkbox"/>
5	0	0	0	0	0	0	0	0	0	0	<input type="checkbox"/>
6	0	0	0	0	0	0	0	0	0	0	<input type="checkbox"/>

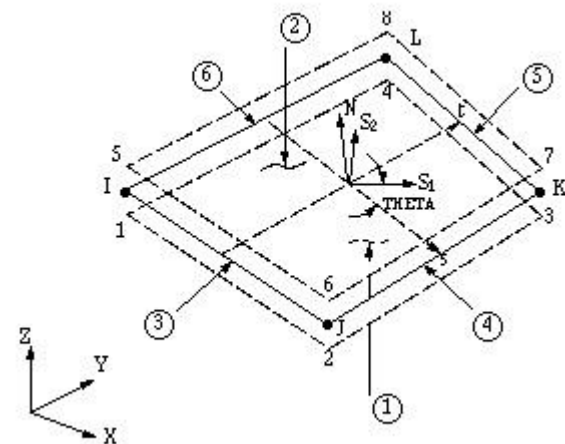
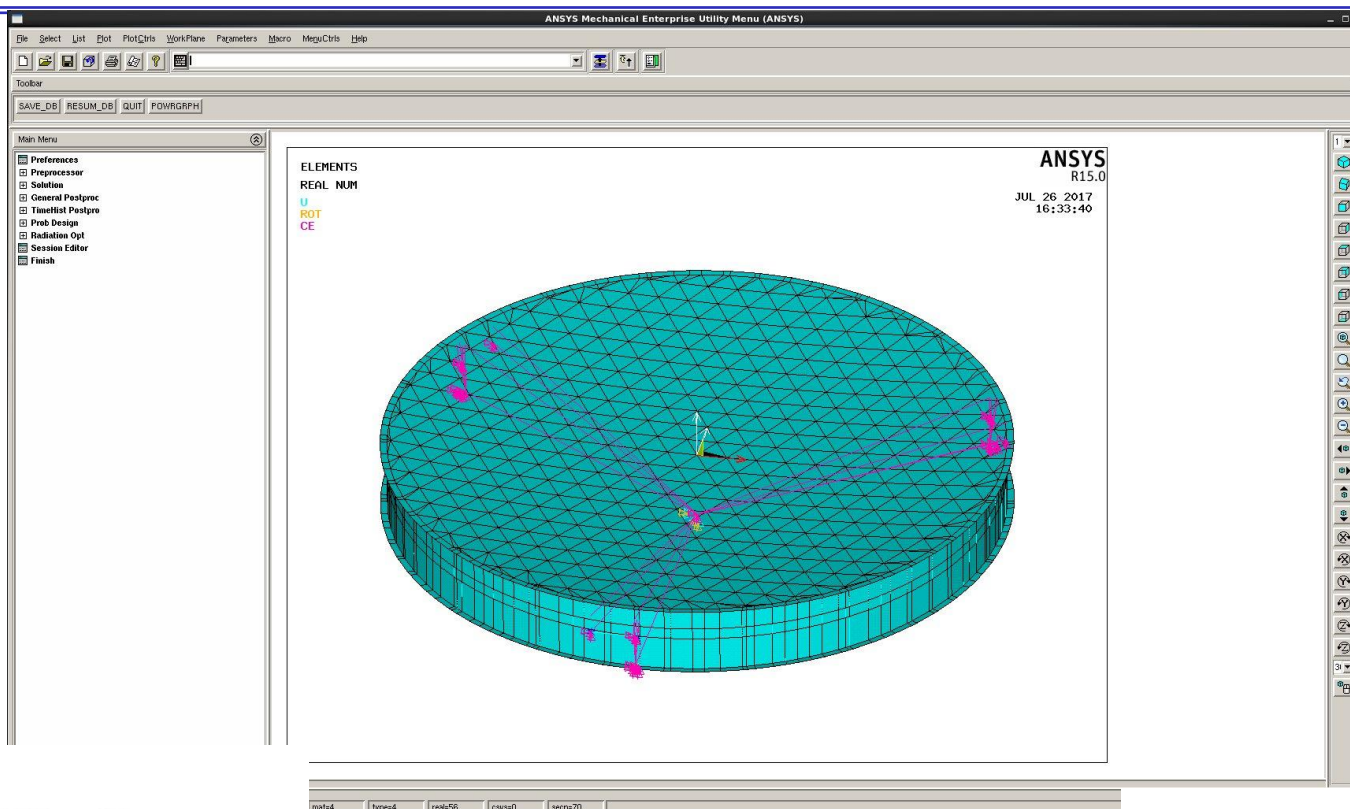


# technology vs. constraints

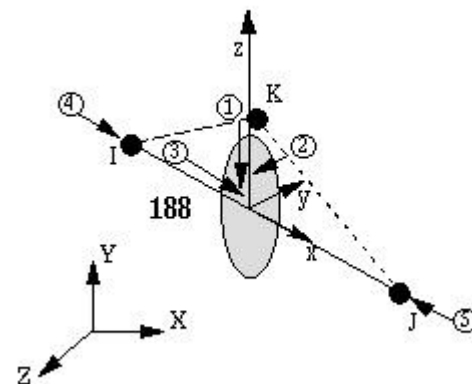




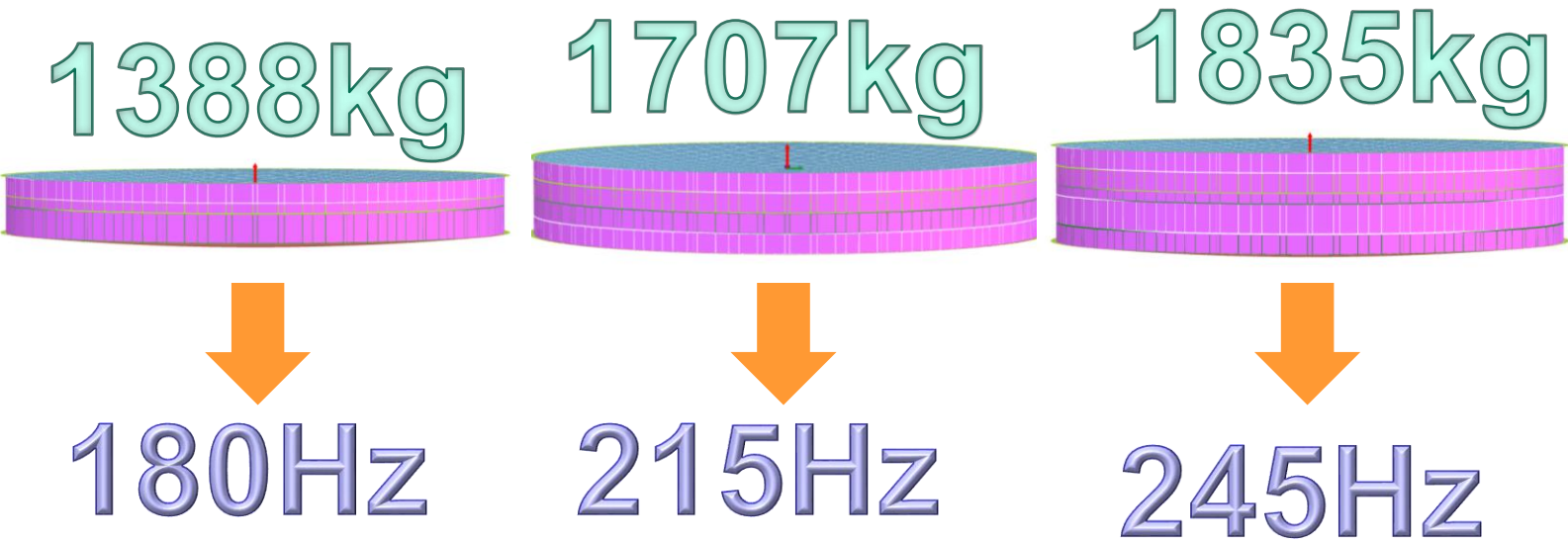
# Finite Element Model



elastic modulus =  $6.76 \times 10^{10}$  Pa  
density =  $2210 \text{ kg/m}^3$   
viscosity =  $0.17$   
thermal expansion =  $3 \times 10^{-8} \text{ m/m/K}$

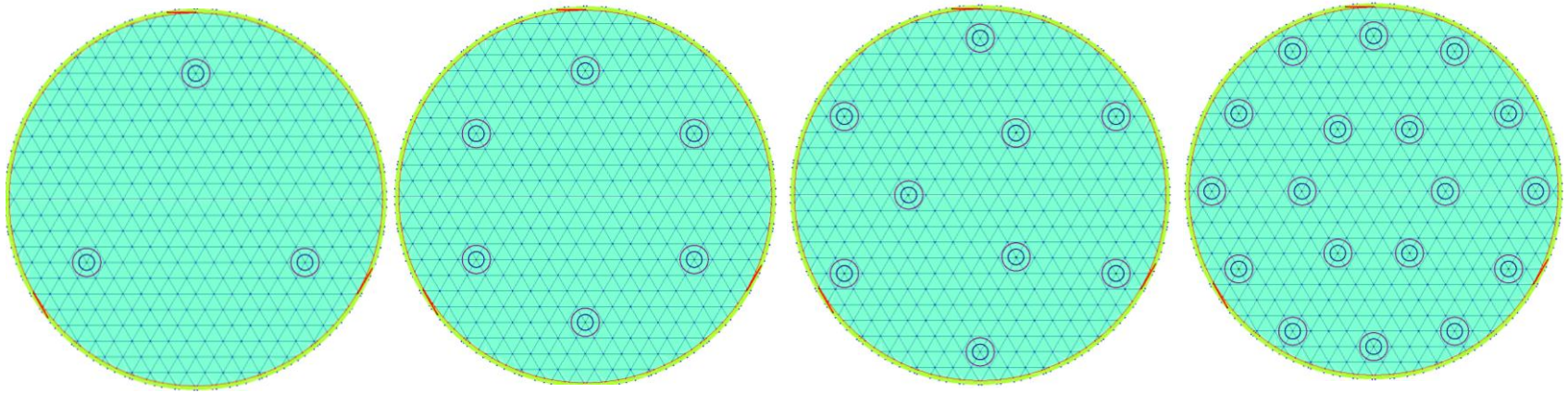


# Stiffness Analysis



depth (m)	0.45	0.6	0.75
mass (kg)	1388	1707	1835
cell size (m)	0.167	0.167	0.167
front fs (m)	0.0277	0.028	0.0277
back fs (m)	0.0231	0.023	0.0231
1st mode (Hz)	180	215	245

# Gravity Sag

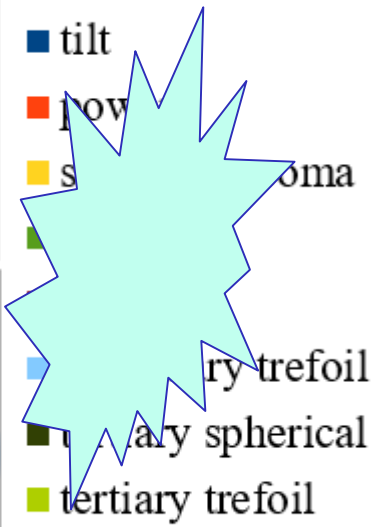
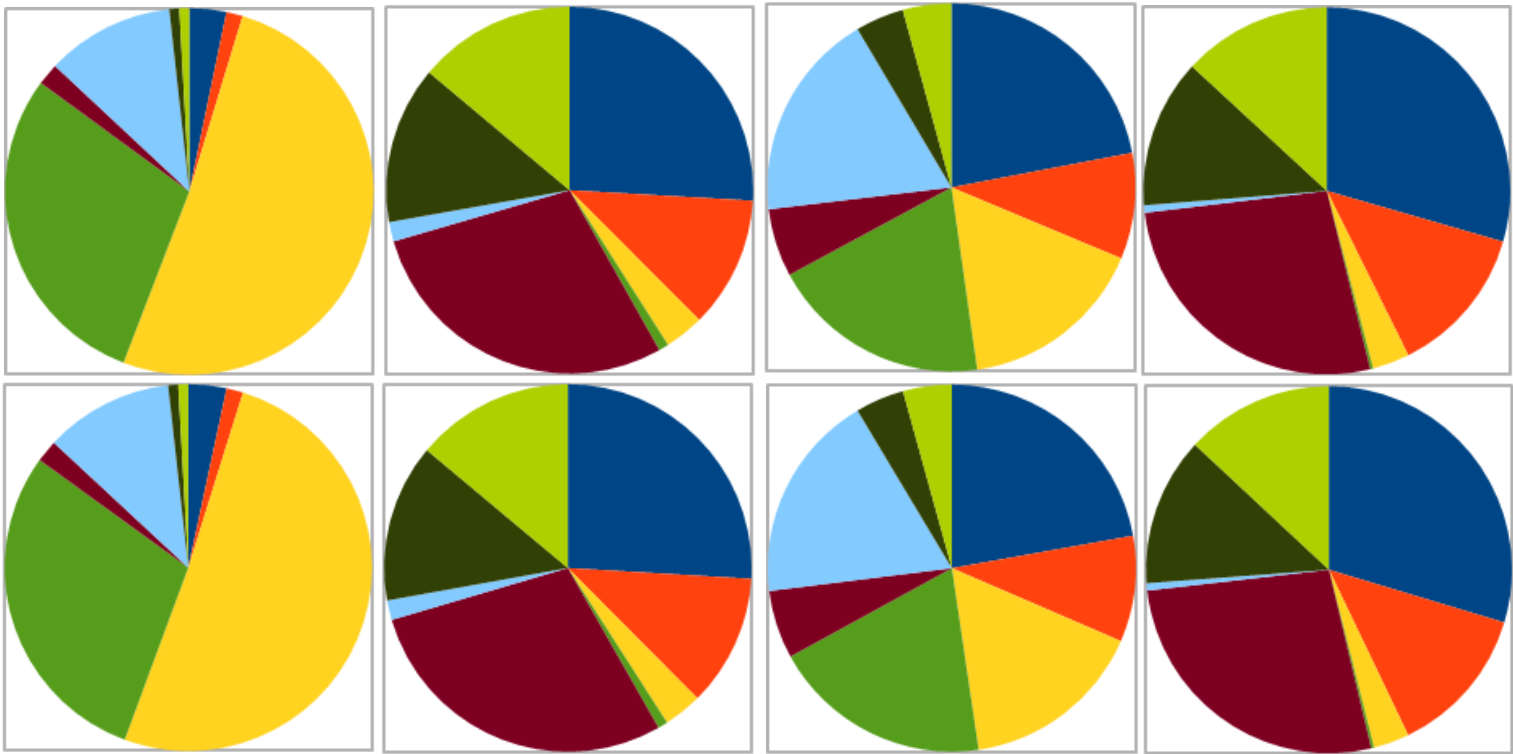


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# Mounting Effects

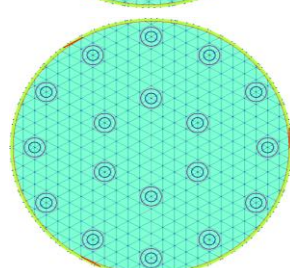
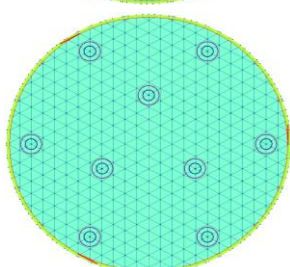
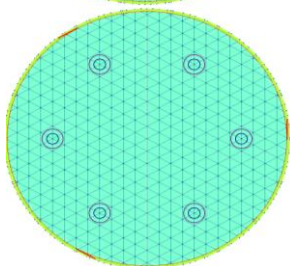
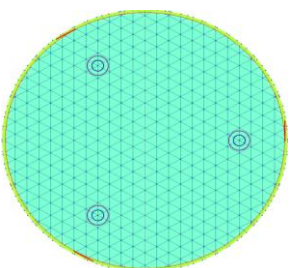
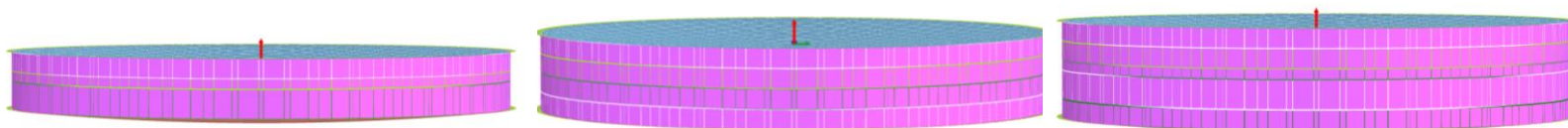
3POINT      6POINT      9POINT      18POINT

\* very stiff mounts



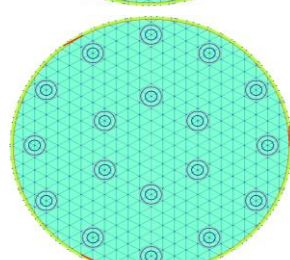
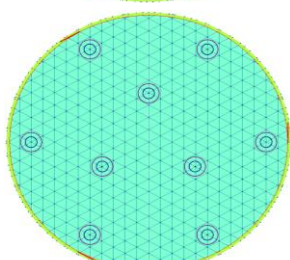
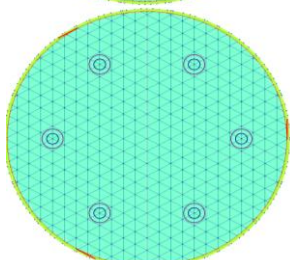
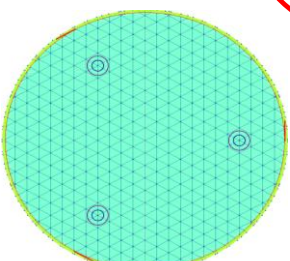
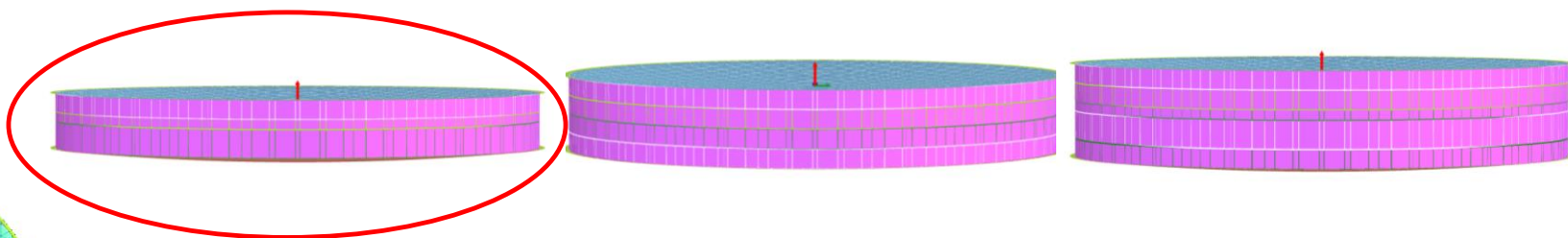


# HabEx 4-meter Off-axis Point Design



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1st mode (Hz)	180	215	245
3-point Vertical Gravity Sag [ $\mu\text{m}$ ]	9.73	7.28	5.41
6-point Vertical Gravity Sag [ $\mu\text{m}$ ]	3.49	2.63	1.97
9-point Vertical Gravity Sag [ $\mu\text{m}$ ]	2.47	1.39	1.39
18-point Vertical Gravity Sag [ $\mu\text{m}$ ]	1.12	1.00	0.80

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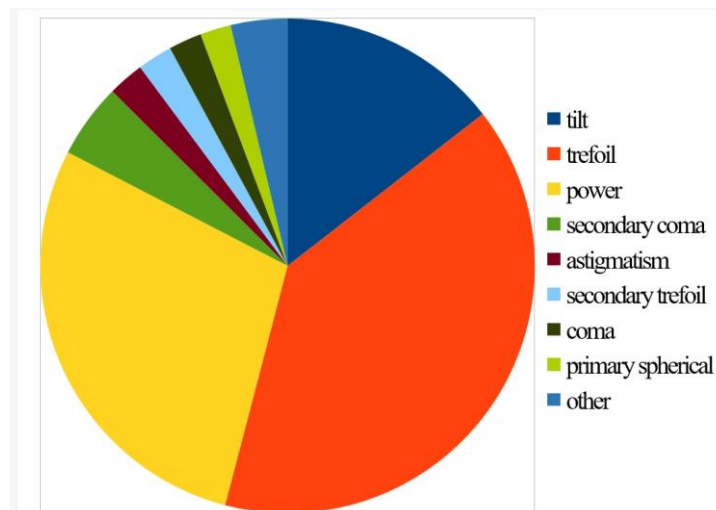
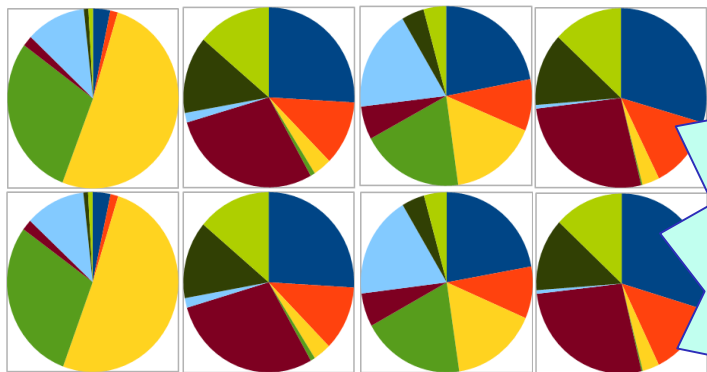
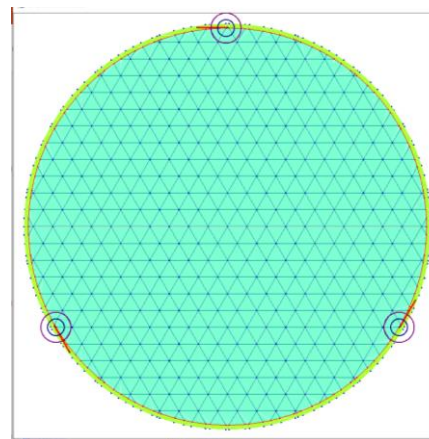
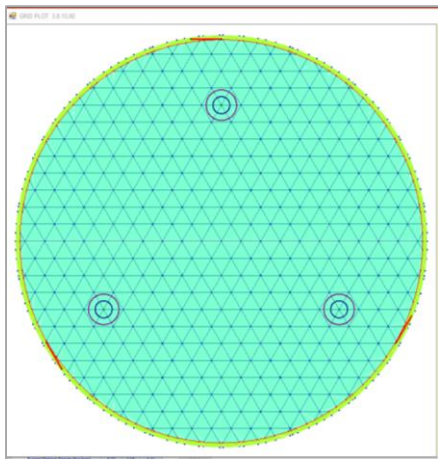


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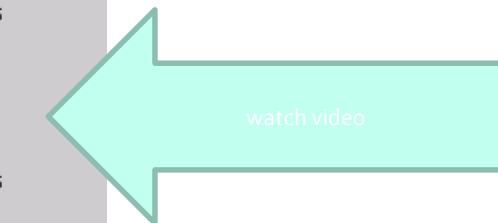
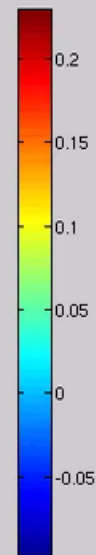
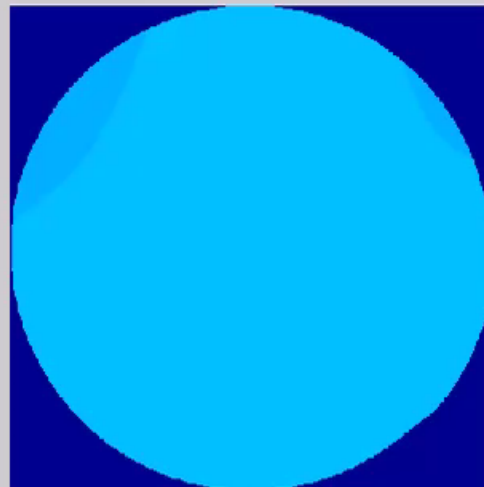


# Change mount placement

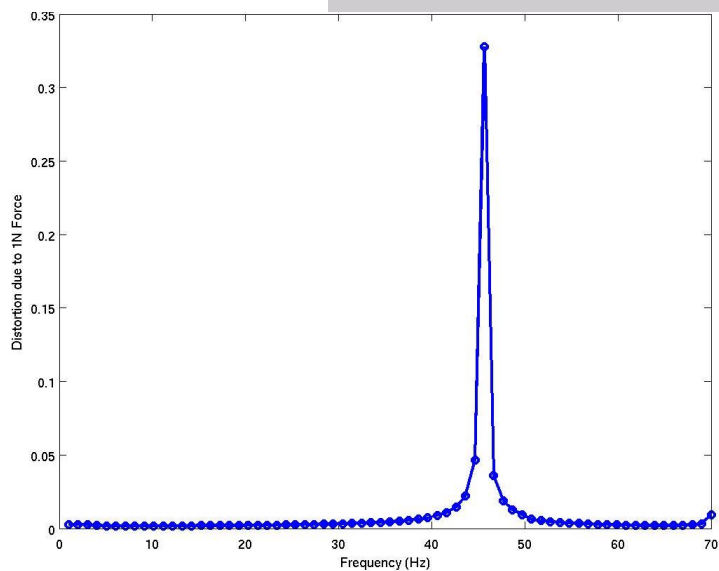




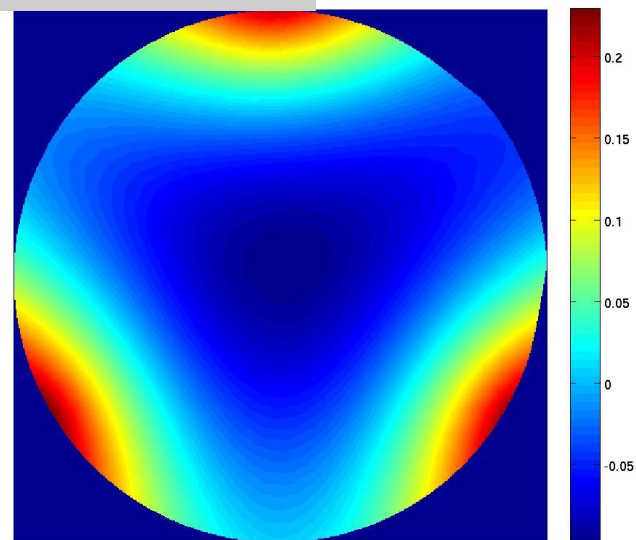
Surface Distortion for 3 Point Mount at Frequency 1.0145 Hz



p-v surface distortion (nm) vs frequency (Hz)

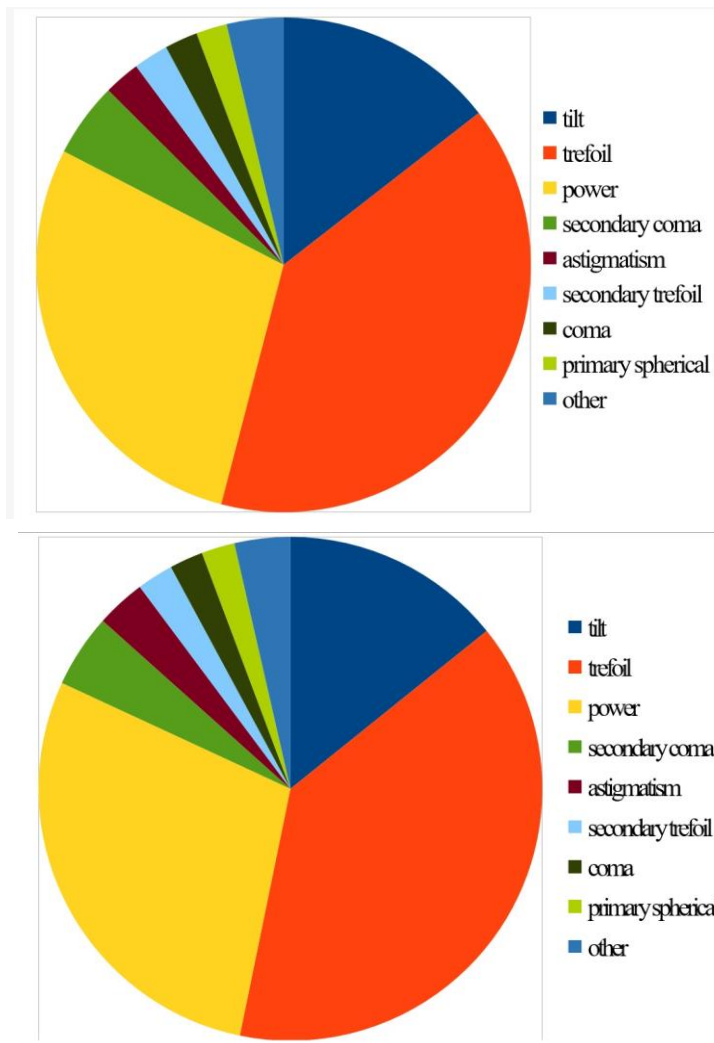


maximum surface distortion (nm)



# Harmonic analysis

	harmonic	gravity sag
magnitude (m)	9.90E-010	2.39E-005
tilt	14.5%	14.2%
trefoil	39.6%	39.0%
power	28.5%	28.7%
secondary coma	4.9%	4.7%
astigmatism	2.4%	3.2%
secondary trefoil	2.3%	2.3%
coma	2.2%	2.2%
primary spherical	2.0%	2.1%
other	3.7%	3.6%



# Mount Stiffness Analysis

